Pre-Registration Synopsis

On

# PROCESSING, CHARACTERIZATION OF PARTICULATE FILLED EPOXY BASED COMPOSITE FOR WEAR APPLICATIONS

For the Doctoral Degree

In

**Mechanical/Production Engineering**

Presented

By

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## Introduction:

Composites are defined as materials consisting of two or more distinct phases with a recognizable interphase between them. They can be classified based on their matrix nature (metal-, ceramic – or polymer-based, thermoplastic and thermosetting polymers), origin (natural, synthetic), appearance (e.g. discontinuous or continuous fibers) and alignment (e.g. random, unidirectional, cross-ply) of the fiber reinforcement, fiber architecture (e.g. non-woven, woven, knitted, braided), etc

In the recent decade, polymeric based epoxy composite materials are finding increasing use in various applications due to several attractive properties, including light weight, ease of processing and cost-effectiveness. They are finding ever increasing usage for numerous industrial applications such as bearing material, rollers, seals, gears, cams, wheels, clutches and transmission belts etc Hence, attempts have been significantly made to utilize polymers in different industrial applications, using various kinds of reinforcements (micro, Nano- fillers, fibers, whiskers, etc) that are incorporated into the polymers to increase their physical, mechanical and tribological properties.

Thermoplastics occupy only a small percentage of the advanced composite market, while thermoset (i.e. Epoxy resin) materials contribute to more than 70 percent. Due to their inbuilt entanglement structure, these resins are the most important polymers when it comes to high performance. Epoxy is a versatile and widely accepted matrix material for fabrication of advanced composites, hardware components, electrical circuit board materials and missile equipment's. However, the use of thermoset materials is often limited because of low toughness property. The properties of the resulting polymer composites depend on the characteristics, the dimensions, and the shapes of the reinforcements, and also on the interfacial bonding strength. It is proposed that with decreasing filler dimensions or increasing filler content there is a significant improvement in the

contact area between the filler and matrix, and in turn it would greatly and effectively improve the transfer of the load between the fillers and the polymer matrix.

With the booming of Nano-phased materials in the recent years, attempts are being made to develop Nano- particle filled-polymer composites. It is expected that good tribological properties can be obtained for the polymers filled with Nano-scale fillers compared to those filled with micro-scale particles. Very little information concerning the wear performance of Nano and micro- filler reinforced composite materials has been reported. So, it is proposed to undertake research on micro, nano particulate filled Epoxy based composite for wear applications.

Due to increased environmental awareness and having more environmental regulations, the growing demand for using nonconventional materials leads to the development of renewable, recyclable, biodegradable, sustainable and eco-friendly materials. The environmental benefits of polymer composite accrue well beyond the production phase. Since the composites are lighter in weight, they reduce fuel consumption as well as carbon dioxide emissions and air pollution. Generally, two important advantages of polymer composites are recyclability and biodegradability of products, after a useful life.

## Literature Review:

This chapter deals with the background information to be considered for the research work and focuses on the relevance of the present study. It embraces some related aspects of particle filled polymer composites with special reference to their mechanical and tribological characteristics.

A literature survey indicated that the sundi wood dust reinforced epoxy composite was processed with seven different filler wt. %. The tensile and flexural tests were performed at three different speeds to study the mechanical behaviour of the

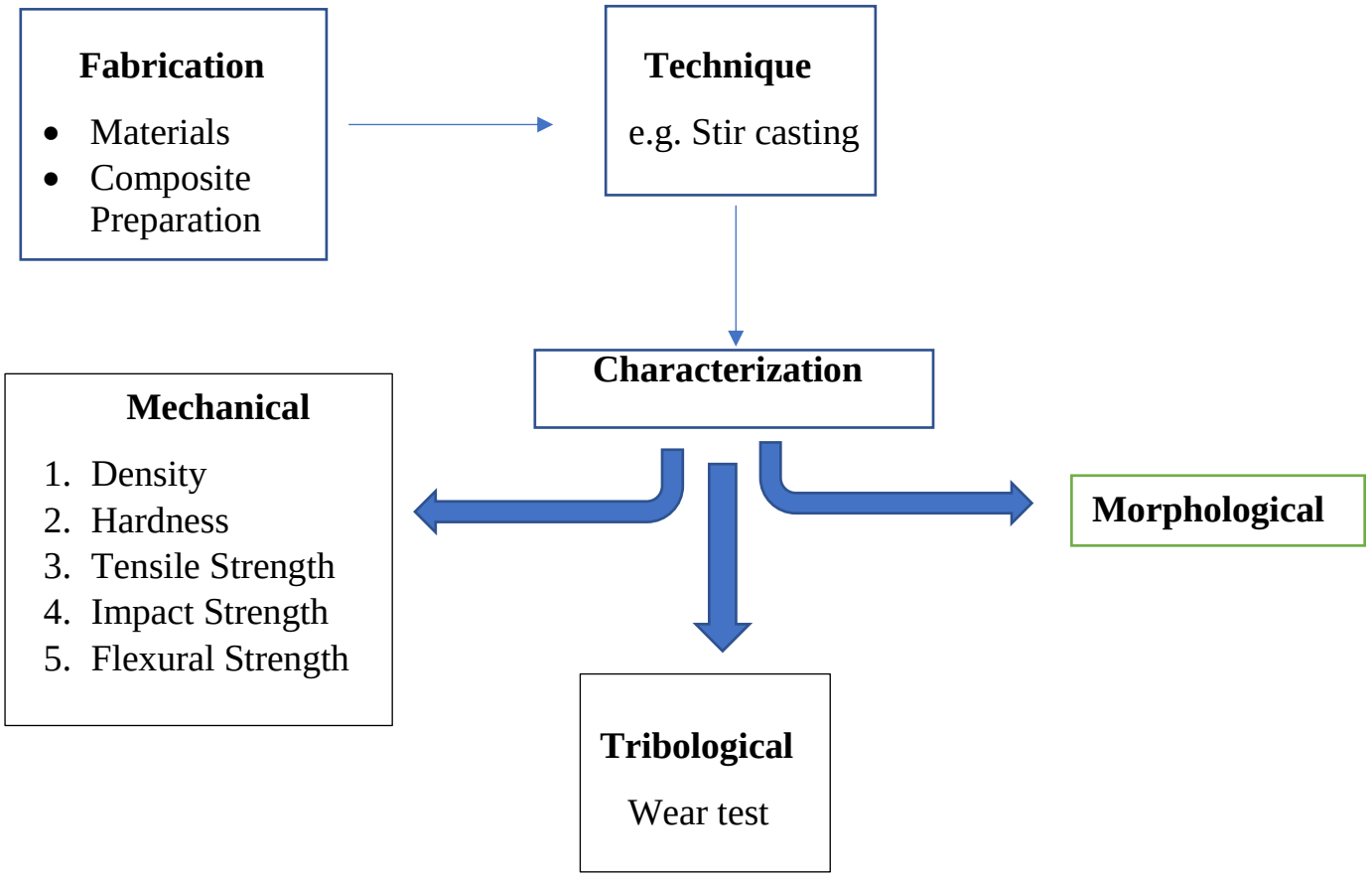
composites. From the observation it was found that the mechanical property increases up to certain filler percentage and then the properties gradually decrease. The microstructure of the composites was also studied to analyze the change using scanning electron microscopy by Rahul Kumara, Kausik Kumarb, et.al [1]. Lingaraju et. al. [2] studied the mechanical properties of fiber-reinforced composite, which showed improvement by the inclusion of nanoparticles. Addition of 1%wt. of silica showed improvement in impact strength, tensile strength, Barcol hardness and reduction in wear rate. Ricardo Baptista et. al. [3] studied the effect of the incorporation of different amounts of graphite filler on the mechanical properties of epoxy resin and of carbon fiber reinforced epoxy composites. Graphite-reinforced epoxy resin attained results show that 7.5, 10 and 11.5 wt.%-graphite results in the best balance of mechanical (modulus, strength, strain) properties and that the incorporation of graphite as matrix filler in carbon fiber reinforced epoxy results in improvement on mechanical properties, up to a limiting value. Bhadrabasol Revappa Raju et. al. [4] investigated that, in abrasion mode, the wear volume decreases as the filler loading increases and it increases with increasing abrading distance. The excellent wear resistance was obtained for $Al_2O_3$ filled G-E composites. M. Sudheer et. al. [5] analysed that the strength properties of composites were slightly reduced after addition of whisker. However, incorporation of solid lubricant as secondary filler resulted in improvement of both mechanical and tribological properties of composites. Ramesh chandra yadaw, sachin Chaturvedi, et. al. [6] did an investigation of Mechanical and Sliding Wear Behavior of Glass Fiber Reinforced Polymer Composite with or without Addition of Silica ($SiO_2$) and concluded that mechanical properties of the composites such as hardness, tensile strength, flexural strength, impact strength, etc. are greatly influenced by the filler content. The morphology of fractured surfaces is examined by using SEM and it has been concluded that the good interfacial bonding is responsible for higher mechanical properties.

An experimental study was conducted by Shakuntala Ojha et. al. [7] to compare the erosive wear behaviour of both raw and carbon black wood apple shell particles filled epoxy resin matrix composites and concluded that the carbon black particulates composite shows minimum wear as compared to raw particulate composite. J Sudeepan et. al. [8] studied the tribological behaviour of polymer composite material prepared using acrylonitrile-butadiene styrene (ABS) as the base material and micron-sized zinc oxide (ZnO) as the filler and concluded that with the addition of filler the friction coefficient and wear rate decrease with an increase in load and speed. N. Mohan et. al. [9] investigated the effect of incorporation of WC on erosive wear behaviour of glass epoxy composites and concluded that the addition of fillers improved erosion resistance and SEM studies of worn surfaces reveal the wear mechanisms such as fiber breakage, fiber cutting and eroded matrix.

It can be concluded from the literature review that, less attention is paid towards the work on Processing, Mechanical and tribological characterization of Epoxy with particulates as fillers.

- **Objectives of the present work:**
    - Fabrication of a new class of epoxy based composites reinforced with particulate fillers and varying percentage.
    - Evaluation of mechanical properties of the composite such as: Density, Hardness, Tensile strength, Impact strength and Flexural Strength.
    - To predict wear performance by experimentation with dry sliding wear test under various operating conditions.
    - To identify the significant control factors and their interaction predominantly influencing the wear rate of composites by using Taguchi's design of experiment.
    - To study the morphological behaviour of composites.
    - To suggest a suitable application for the developed composite.

## Methodology:




### Step 1: Fabrication

Materials and composite preparation:

Epoxy resin and the corresponding hardener will be used as the matrix material. Addition of fillers in Epoxy resin enhances mechanical, tribological and other properties. Fillers used in polymeric composites can be natural or synthetic, **micro**, **nano**-fillers. More recently new development has shown that much smaller fillers for example, **nano-sized** particles can lead to special effects which cannot be reached so easily with conventional fillers.

The low temperature curing epoxy resin and its hardener are mixed in the same ratio by volume as recommended. Then the required quantities of fillers will be stirred gently in the epoxy resin taking care that no air bubble is entrapped inside

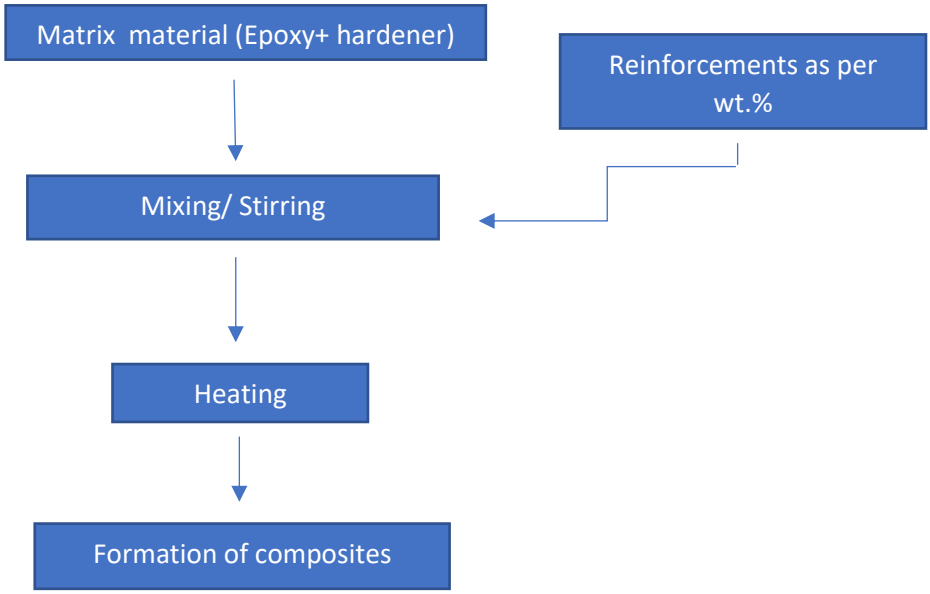
the solution. The mixture is then poured into a metallic mold cavity coated with a silicon based release agent (Spray mould, silicon spray mould release agent used for plastic). The mold is then placed in an electric oven and heated at a constant temperature of 100°C for about 45 minutes. After the mold is taken out the samples are released.

**Step 2: Fabrication Techniques of PMC's**

There are many processing methods of composite materials, and big differences in distinct types of molding processes of composite materials viz. simple stir casting, Hand Lay-Up, Spray-Up, Filament Winding. The stir casting is a simple process which is to be used for preparing thermosetting polymer matrix composites.

**Stir casting:**

The flowchart here shows the procedure of stir casting.



**Step 3: Characterization**

The research will focus on the mechanical and tribological characterization of the composite material made of epoxy resin reinforced with different percentages of particulate fillers.

Mechanical characterization:

The mechanical behaviour of epoxy composite material will be analysed by using tensile test, flexural (bending) test and impact test.

All mechanical tests will be performed at room temperature and as per ASTM standards. Density of test samples is measured as per Archimedes' principle using distilled water as media. Hardness of developed composites is measured using Rockwell hardness tester/Shore-D. Tensile and flexural tests will be carried out on universal testing machine. Impact testing will be done on un-notched test specimens using Izod impact tester.

Tribological characterization:

Dry Sliding wear tests will be conducted by following a well-planned experimental schedule based on Taguchi's design of experiments, considering parameters like Filler content, Normal load, time, Sliding Velocity or Sliding distance, on a Pin-On-Disc set-up.

A Pin-on-Disc set-up is used for slide wear tests. Composite specimens, of required dimensions come in contact with a rotating steel disc while a constant normal load is applied. The weight loss measurements are carried out. The wear is measured by the loss in weight which is then converted into wear volume using the measured density data.

Following equations are used for calculation of wear rate.

i. Volume wear = $\Delta M / \rho$
ii. Sliding Distance (SD) = $2\pi rNt$

iii. Specific wear rate = $\Delta M/SD\rho F$

Where, $\Delta M$= Loss in weight, r = radius of wear track, N= speed of disc in RPM, t = time in minutes, $\rho$ = density in gm/cm$^3$, F= Normal load in Newton.

Morphological Characterization:

To identify the mode of material removal, the morphologies of eroded surfaces are studied. The surfaces of specimens are examined by SEM, XRD, EDX, BET, FTIR, etc

## Expected Outcome:

- The successful incorporation of fillers into epoxy matrix, for intended purpose.
- The addition of fillers in epoxy to show a noticeable effect on mechanical properties of the composites.
- Improved wear resistance property, successful analysis of Dry sliding wear response of composites by Taguchi's Design of experiment and identification of significant factors affecting the wear rate of composites.
- Useful data base generation.

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